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A Review on Spectrum Sensing Techniques in Cognitive Radio Network

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ABSTRACT- The increasing demand in wireless application leads to burden on unlicensed spectrum band. In other case the licensed bands are seen underutilized which leads to spectrum wastage. The solution for this is use of licensed band by introducing the cognitive radio and Dynamic Spectrum Access. Cognitive radio is an intelligent radio which is aware of the surrounding environment. DSA is new spectrum sensing technology that allows the secondary user to access the spectrum hole from licensed spectrum band. The function performed by the cognitive radio are spectrum sensing, spectrum management, spectrum mobility and spectrum sharing. Spectrum sensing is the main function of a Cognitive Radio. This paper presents survey of spectrum sensing techniques in Cognitive Radio. The focus of article is types of spectrum sensing techniques such as single band and multiband.

KEYWORDS- Cognitive Radio, Spectrum Sensing, Single band spectrum sensing , Multiband spectrum sensing.

I. INTRODUCTION

Because of rapid growth in wireless communication there is a huge demand in wireless technology and this burdens on unlicensed spectrum band. Major licensed band which are allocated for television, surveillance radar, paging have been grossly underutilized and because of that it results wastage in spectrum space [1]. For the better use of licensed spectrum band the Federal communications commission (FCC) introduces the new spectrum sharing strategies using DSA and Cognitive radio. Cognitive Radio is an emerging advanced radio technology.

The spectrum utilization of licensed spectrum band taken over 30 MHz to 3 GHz averaged in different locations is shown in Figure 1. As shown in figure the licensed band has low utilization which results in spectrum Scarcity [3]. Hence there is need of secondary systems to monitor the licensed spectrum band and transmits when it is not occupied by licensed/ primary user [3]. To find out the solution for above problem FCC has introduced the cognitive radio as secondary system. Cognitive Radio achieves effective spectrum utilization by finding and using available licensed spectrum band. The cognitive radio senses the licensed spectrum band to find out the presence of licensed/ primary user in that band [3].

Cognitive radio is an intelligent radio which can monitor, sense , detect and adopt the radio parameter by accessing the dynamic frequency spectrum band [3].

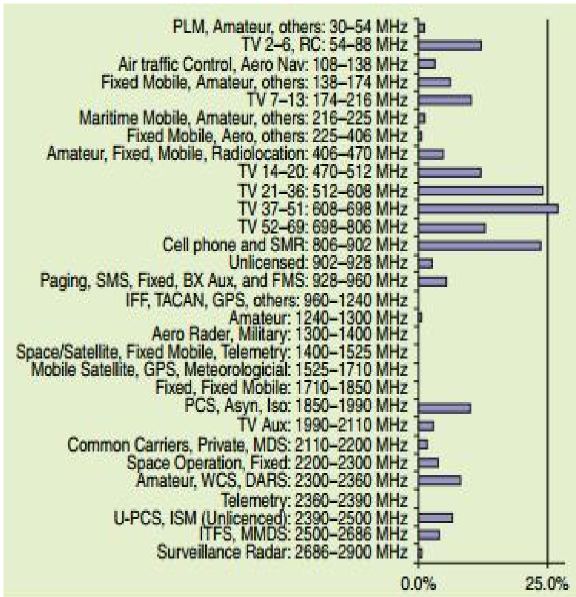

Figure:-1 Spectrum utilization taken over 30 MHz to 3GHz [2]

A) Cognitive Radio

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The definition adopted by FCC : "Cognitive Radio is a system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operations such as to maximize throughput, mitigate interference, facilitate interoperability, access secondary markets" [4].

Cognitive radio senses, monitors the licensed spectrum band and gain the knowledge of parameters like channel characteristics, availability of spectrum band, available nodes etc [4].

Cognitive radio application includes military and public security, healthcare, home appliances, transportation, vehicular networks, real time surveillance applications etc.

B) Cognitive Radio Characteristics

Cognitive Radio technology is the emerging technology in today's world. It enables the cognitive network for the usage of underutilized licensed spectrum band. By interacting with the environment in which it operates , it changes its transmission parameter according the sensed environment. There are two important characteristic of Cognitive radio.

1. Cognitive Capability

A. Cognitive radio when interact with the real time environment it receives the necessary information about the radio parameter. As the cognitive radio is an intelligent radio it can adopt their operating parameters like modulation type, frequency according to variations in surrounding radio environment. This characteristic of cognitive Radio is called as cognitive capability. The cognitive radio cycle is as shown in figure 2 [7]. It shows the task that are required for adaptive operations for Cognitive Radio. The task performed by cognitive radio network is shown in figure 2 includes spectrum sensing , spectrum analysis and spectrum decision [7]. Spectrum sensing

In this the cognitive radio monitors the surroundings environment or available licensed spectrum band to detect spectrum hole or white spaces. White spaces is that portion of bands in which primary user is not present.

B. Spectrum analysis

In this spectrum hole characteristic detected in spectrum sensing are estimated.

C. Spectrum decision

By determining the parameters like bandwidth, data rates, transmission mode it can select the appropriate spectrum band for transmission of signal. If the primary user approaches this band then secondary user changes their transmission to other available spectrum band.

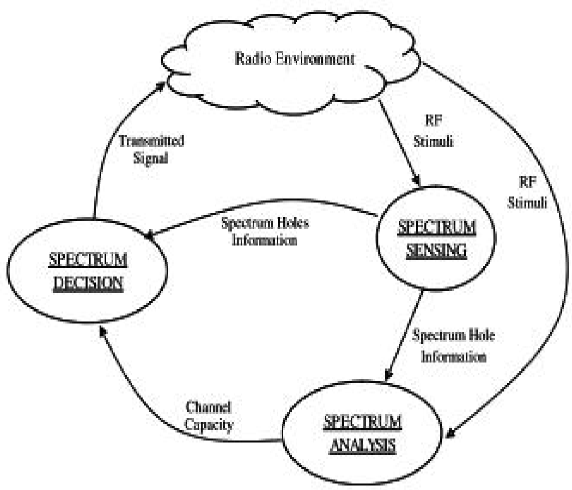

Figure 2:-Cognitive Radio Cycle [7]

2. Reconfigurability

By sensing the radio environment the cognitive radio gathers all the needed information and changes their transmission parameter without any modification in hardware. By using reconfigurability the cognitive radio can easily choose the dynamic radio environment. Several reconfigurable parameters are modulation, operating frequency, transmission power and communication technology.

C) Functions of Cognitive Radio

The functions performed by Cognitive Radio are shown in Figure 3 such as Spectrum Sensing, Spectrum Management, Spectrum Mobility , Spectrum Sharing.

a. Spectrum sensing

Spectrum sensing is an important element in establishing the Cognitive Radio Network. In this the Cognitive Radio senses the available licensed spectrum band to find out the vacant spectrum band and existence of primary user in that band.

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b. Spectrum management

In cognitive Radio network the unused band including the licensed and unlicensed band are spread over a wide frequency range so that the cognitive Radio can capture the best available channel considering the user communication requirement.

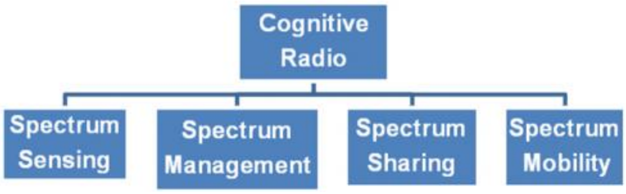

Figure 3:- Function performed by Cognitive Radio [7]

c. Spectrum mobility

When the secondary user uses a particular spectrum band and if primary user appears in that band the secondary user have to quit that band by changing its frequency of operation and goes to another available spectrum band is needed. This is also termed as spectrum handoff. The purpose of spectrum mobility management in Cognitive Radio Network is to make sure that transition are made smooth for seamless communication.

d. Spectrum sharing

Spectrum sharing includes the spectrum scheduling techniques among the coexisting cognitive radio users. Spectrum sharing includes the major steps like spectrum allocation, spectrum access, transmitter and receiver handshakes etc.

In cognitive radio a major challenge is to detect the unused spectrum frequencies for the transmission of signal of secondary user. This technique is called spectrum sensing. Spectrum sensing and estimation is the first step to implement Cognitive Radio system.

D) Spectrum Hole Concept

In spectrum sensing the Cognitive Radio detects the vacant spectrum band called as spectrum hole or white spaces.

White space are that band of portion which is not occupied by primary user. Spectrum holes are those sub bands which are underutilized. These sub bands are partially full at particular instant of time in geographic area. Secondary user can uses this band for their operation and utilize the spectrum efficiently. If this spectrum band is further used by primary user then the secondary user must have to leave this band and goes to another available spectrum band to avoid interference between licensed and unlicensed user.

In radio spectrum sub bands can be categories as follows[5]:

A. **White spaces**: They are free of RF interference except for white Gaussian noise**.** These spectrum holes are not fully used.

B. **Gray spaces:** They are partially dominated by low-power interference. These spectrum holes are partially used.

C. **Black spaces:** They are dominated by high-power "local" interference sometime. These spectrum holes are fully used.

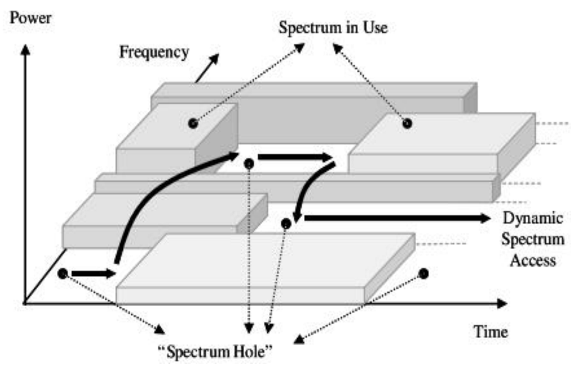

Figure 4:-Spectrum hole concept in licensed spectrum band [5]

Figure 4 shows the spectrum band which are in use and which are partially full. It shows the concept of spectrum hole in spectrum band. In spectrum sensing the most challenge is to share the spectrum without interfering to the licensed spectrum band and hence finding spectrum hole is important task to performed.

II. SPECTRUM SENSING TECHNIQUES

Spectrum sensing can utilize the spectrum efficiently by detecting the unused licensed spectrum band and make them available to unlicensed user. This lowers the burden on wireless communication network by using the underutilised licensed band. To detect the presence of primary user a different techniques can be

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evolved [3]. By using these techniques signal type can be identified. Using these techniques characteristics of the identified transmission are detected for the transmission of signal. There are two types of spectrum sensing technique in a Cognitive Radio.

1) Single band Spectrum Sensing
2) Multiband Spectrum Sensing

➢ Single Band Spectrum Sensing Techniques

Using spectrum sensing techniques the cognitive radio can detect the presence of primary user and also detect the spectrum hole by observing the surrounding spectrum band [6]. Only with this above information cognitive radio can adapt their transmission parameter like modulation , operating frequency, transmission power etc, to utilize the spectrum efficiently [6].

The classical binary hypothesis testing problem for single band spectrum is as follows [7]

$$y(t) = \begin{cases} w(t) & H_0 \\ h.x(t) + w(t) & H_1 \end{cases} \quad ....(1)$$

Where y(t) is the received cognitive radio signal, w(t) is the Additive White Gaussian Noise (AWGN) signal, x(t) is primary user signal, h is the amplitude gain of channel. H_0 is the null hypothesis which shows absence of primary user signal in spectrum band. H_1 is the hypothesis which states the presence of primary /licensed user in certain spectrum band[7].

By observing the signal y(t) the cognitive radio needs to decide the signal between H_0 and H_1

I. Classification of Single band Spectrum Sensing

Single band spectrum sensing is classified as follows

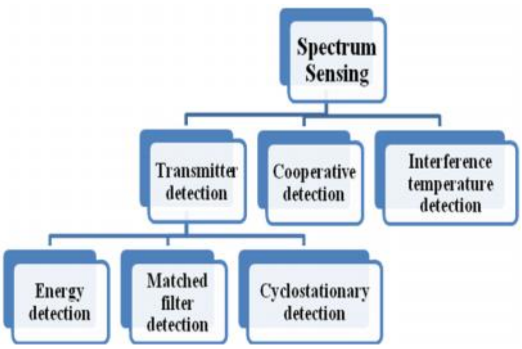

Figure 5:-Classification of spectrum sensing techniques [7]

There are three types –Transmitter detection or non cooperative sensing, Cooperative sensing, Interference based sensing. Figure 5 shows the detailed classification of spectrum sensing techniques.

1. Transmitter detection

Transmitter detection technique is further classified into energy detection, matched filter detection and cyclostationary feature detection[7].

A. Energy Detection Technique

This is the non coherent detection method. Based on sensed information it detects the presence of primary signal. For energy detection method there is no need to have a prior knowledge of primary signal. It is very simplest method among all detection methods.

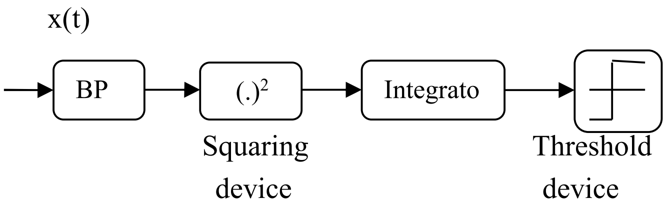

Figure 6:- Block Diagram of Energy Detector [9]

Figure 6 shows the block diagram of energy detector, In this detector the signal having bandwidth W and the frequency F_s is passed through the band pass filter. This filter is followed by the squaring device then that signal is integrated over time interval T. The output of integrator (Y), is then compared with the threshold (λ) and according to decision the detector detects the presence or absence of primary user signal [9].

B. Matched Filter Detection

Matched filter detection method is advance than energy detection method. Matched filter detection method is used when the information of primary user signal is known [11].When the secondary user knows the prior knowledge of primary user signal like its modulation type, packet information, order and pulse width we can apply this method for detection of signal. This detection method uses the method correlation. In correlation the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of reference signal [10]..

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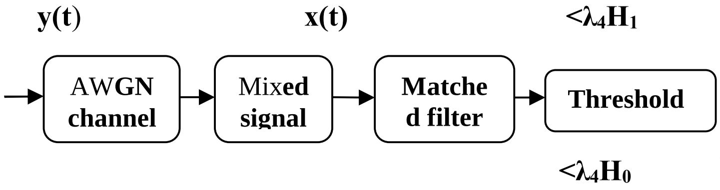

Figure 7:-Block Diagram of Matched Filter [10]

The operation for matched filter method is given as

$$y(t) * x(T-t+\tau) \quad (2)$$

Here y(t) is the received signal which convolved with the time –reserved version of known signal, T is time duration symbol, τ is the shift in known signal x(t). The output of matched filter is compared with the threshold (λ_4) to decide the presence or absence of primary signal as shown in figure 7 [10].The main advantage of this detection method is that it require less time to achieve high processing gain due to coherency.

C. Cyclostationary Feature Detection

The cylcostationary feature detection can be obtained by analysing Cyclic Autocorrelation Function (CAF) of the received energy signal. Cyclostationary feature detection is capable of differentiating the primary user signal from noise and interference and due to its property of noise rejection it better works in low SNR region. Due to its robustness to uncertainty in noise power, the detector performs better than traditional detectors like energy detector against the noise [1][12].This detector enhances the detection capability in presence of noise power uncertainty. This detector uses the modulated signals which are in coupled with sine wave carriers, pulse trains , frequency hopping etc[7][13].These modulated signals are then characterised as cyclostationary since their mean and autocorrelation exhibits periodicity. However, this feature detection technique is computationally complex and requires significantly long observation time [7][14]. Traditional detector like energy detector uses time domain as the test statistics, the cyclostationary feature detection transform time domain into frequency feature domain and conduct hypothesis in the new domain [6].

2. Cooperative Detection Technique

Due to single cognitive radio transmitter and receiver users, in practices many factors arises such as multipath fading, shadowing, receiver uncertainty problem which also degrade the detection performance in spectrum sensing. The performance degradation due to multipath fading, shadowing can be overcome by cooperative sensing because of its improved sensing ability [7].

In this detection technique multiple Cognitive Radio users is used to detect primary user signal. The information from multiple Cognitive Radio users is collected and based on results the detection of presence of primary user signal is done. As the multiple Cognitive Radio users shares the sensed information and combined their results to detect primary user signal is more accurate than individual one [19].Cooperative detection can be implemented either in a centralized or in a distributed manner [18].

A. Centralized Cooperative Sensing

Here the central identity called Controller (C) of the network.

As shown in figure 8 CR_0 is the Controller of the network and CR_1—CR_5 are the Cooperative Cognitive Radio users. All these Cognitive Radio users performs individual local sensing and sends the combined result to controller CR_0.

All the sensed information is send through the reporting channel. There is point to point link between all Cooperative Cognitive Radio users for data reporting through control channel[15][17].

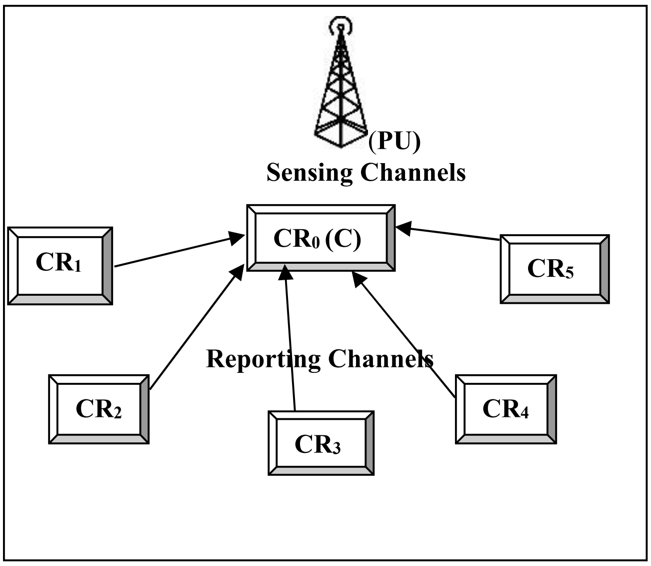

Figure 8:- Centralized Cooperative Sensing technique[15]

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B. Distributed Cooperative Sensing

The distributed cooperative sensing the decision of detecting primary user does not depends on the controller of network. Here the Cooperative Cognitive Radio users communicate among themselves and make the unified decision on presence or absence of primary user signal [15].

Controller selects the channel or frequency band for sensing and instruct all the Cognitive Radio users in that network to perform individual local sensing. All Cognitive Radio users in that network reports their results through the control channel to controller. Then the controller combines the result of local sensing and determines the presence or absence of primary user signal and sends this decision to all Cooperative Cognitive Radio users[15][16].

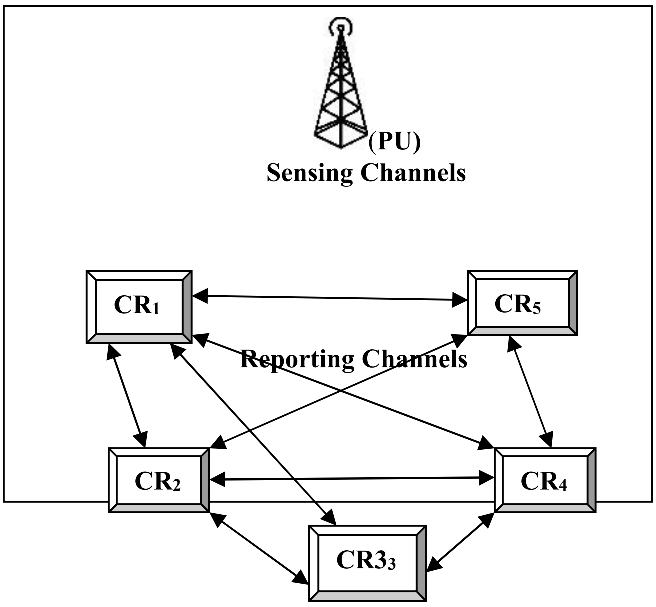

Figure 9:- Distributed Cooperative Sensing technique

Figure 9 shows the cooperation in the distributed manner. Here the CR_1-CR_5 performs the local sensing operation. They all are combines their results with each other based on distributed algorithm. Each Cognitive Radio user send their sensed data to other users and combined them with received sensing data and decides the presence of primary signal [15]. This process is repeated until the algorithm is meet and decision is reached.

3. Interference based detection technique

The interference temperature method is basically focuses on measuring interference at receiver [21]. The idea behind this method is to set up an upper interference limit for a given frequency band in specific geographic area so that cognitive radio is not allowed to cause any harmful interference while using that band at that time [20]. Cognitive Radio transmitter control their interference by regulating their transmission power based on their location.

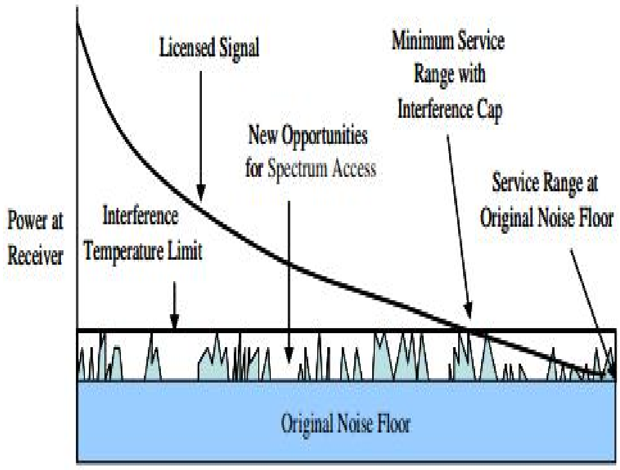

Figure 10:- Interference temperature model representation [7]

Figure 10 shows a model of interference temperature which is introduced by FCC. The interference temperature model provides a maximum amount of tolerable interference for a given frequency band in specific geographic area. This model measures the RF power available at receiving antenna to delivered to receiver and also reflects the power generated by noise sources and emitters. [20]. Interference based detection includes the factors such as type of unlicensed signal modulation, ability to detect active licensed user, power control etc [7].

III. COMPARISON OF VARIOUS SENSING METHODS

Table 1 shows the comparison between the Non cooperative sensing methods which are energy detector , matched filter detector and cyclostationary feature detection.

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Spectrum sensing algorithm	Advantages	Disadvantages
Energy Detector	Do not require prior knowledge of Primary User, have low computational cost	Poor performance for low SNR
Matched filter detection	Requires prior knowledge of primary user. Have low computational cost	Requires prior knowledge of primary user
Cyclostationary feature detection	Robust against interference. Valid for low SNR level.	High computational cost

Table 1:- Comparison of transmitter detection technique [6]

- **Multiband spectrum techniques**

In multiband spectrum access multiple bands are sensed and access to enhance the networks throughput, to improve spectrum maintenances by reducing handoff frequency[25]. Here the basic principle is to enable the secondary / cognitive users to simultaneously access multiple bands and because of this more spectral opportunities will be utilized [22].

There are several scenarios where the need of multiple band cognitive radio network can be encountered as [23].

1. Today's modern communication and applications requires a wideband spectrum access. The wideband spectrum is divided into multiple channels or multiple bands. Hence there is need of multiband detection problem arises.
2. To achieve the higher throughput and to maintain the certain quality of service (QOS) the secondary user transmits the signal over a larger bandwidth which is possible by accessing wideband spectrum.
3. By returning of primary user to their band there is possibility of data interruption. To minimize the data interruptions, the secondary user wants to seamless handoff from one spectrum band to another band. For that the secondary user must have a backup of another channel besides those channel it is currently using. With the help of multiple band cognitive radio network the secondary user have a set of candidate channel [24].

In multiband spectrum sensing the wideband spectrum is divided into multiple sub-bands. As shown in Figure 11 here wideband spectrum band is divided into M non overlapping sub bands. It is assumed that each sub-bands have the same bandwidth. Secondary users primary task is to determine which sub-bands are available for spectrum access.

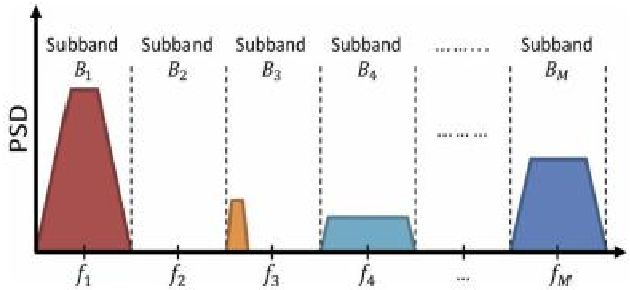

Figure 11:- Multiband spectrum band which are divided into sub bands [23]

By assuming that the sub channels are independent the binary hypothesis for multiband spectrum sensing for each of the channel is expressed mathematically as

$$H_{0,m} : y_m = v_m \qquad m= 1, 2,........,M$$
$$H_{1,m} : y_m = x_m + v_m \qquad m= 1,2,.........,M$$
(3)

Where m is the individual subband or subchannels. The decision rule for each band in multiband spectrum sensing is given as [23]

$$T(y_m) \underset{H_{0,m}}{\overset{H_{1,m}}{\gtrless}} \lambda_m \qquad (4)$$

where T (y_m) is the test statistic of the m-th sub bands, and λ_m is the threshold which divides the decision area into $H_{1,m}$ and $H_{0,m}$

Advantages of Multiband over Single Band Spectrum Sensing:-

1. Strengthen the network's throughput
2. Provide better spectrum channel maintenance by reducing handoff frequency.

1) Classification of multiband spectrum sensing technique

Multiband Spectrum Sensing are classified as Serial based detectors, Parallel based detector and Wideband Based detectors as shown in Figure 12 [23].

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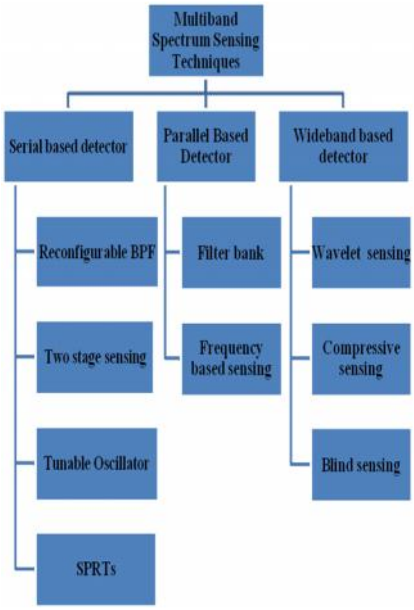

Figure:- 12 Classification of Multiband Spectrum Sensing Technique [23]

1. **Serial Based Detector**

In serial spectrum sensing, single band detectors can be used to sense wideband spectrum one at a time using any of the following techniques

A. Reconfigurable Band pass Filter

In reconfigurable filter it is necessary to have control over center frequency and the bandwidth of the filter because bandwidth of filter is proportional to center frequency and therefore can vary over wide signal range [26]. Figure13 shows the structure of reconfigurable band pass filter here first block is band pass filter which is used to pass the band one at a time. The single band detector is used to determine occupancy of particular band by comparing the output with the threshold (λ_m) [23] .

This reconfigurable band pass filter requires a wideband receiver font end, and hence it creates challenges for hardware implementation because of high sampling rates. Also controlling the cut off frequency and filters bandwidth is the challenging design issues [23].

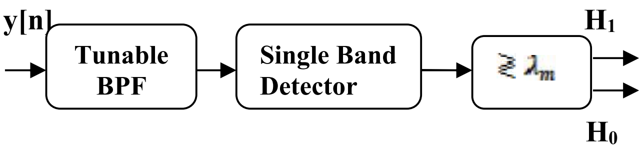

Figure 13:- Reconfigurable band pass filter

B. Tunable Oscillator

Second type of the serial based detector is the tunable local oscillator(LO) band pass filter which down-converts the center frequency of a specific band to fixed intermediate frequency. The structure for this is shown in Figure 14 which will shows significantly reduction in the sampling rate requirement.

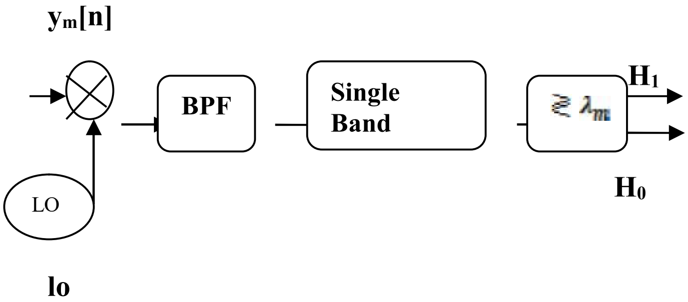

Figure 14:- Local/tunable oscillator [23]

Here in Cognitive Radio as the sensing moves from one channel to other the reconfigurable band pass filter and tunable oscillator requires the tuning and sweeping of the frequencies and this is the main limitation of both the structure. This hampers the fast processing of the detector and thus this both techniques are undesirable to implement [23].

C. Two-Stage spectrum sensing

The two stage spectrum sensing provides the faster detection of signal band than the conventional single stage detector. Here the sensing is performed in two stages. First stage is the coarse sensing followed by second stage fine sensing [23]. The block diagram of two stage sensing is shown in Figure 15.

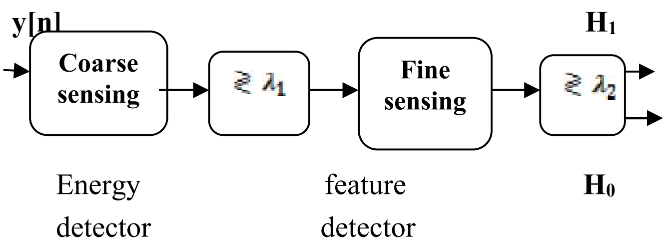

Figure 15:-Two stage serial spectrum sensing technique [23]

Author in [27] discuss that two stage sensing is the divided into several multiple coarse sensing blocks (CSB). In coarse sensing the random search is done over this wide bandwidth. Here the coarse sensing block (CSB) with the idle channel is find out and then that bandwidth is followed by fine sensing. In fine sensing the sensing is done over the individual sub-band of this bandwidth to find out presence of primary signal.

When the primary user activity is high this sensing technique provides faster searching time than one stage detector [23]. Author in [28] discuss that the coarse sensing they used the energy detector for fast processing and for the fine sensing they use the cyclostationary detector. Here in coarse sensing the energy detector searches the possible empty channels, the final decision about the vacancy of the band is done in fine sensing through cyclostationary detector. Here energy detector is used to search the band serially. In this if the energy is detected above the threshold λ then considered as the band is occupied, else the receiver signal is passed through the fine sensing.In fine sensing signal is passed through cyclostationary detector. Here if the constituent of the decision metric is greater than threshold λ then that signal is declared as occupied otherwise the channel is declared as empty for the usage of secondary user [28]

D. SPRTs

Sequential probability ratio tests (SPRTs) is used to serially sense multiple spectrum bands. SPRTs is fast channel searching algorithm. The conventional test algorithms uses a fixed number of samples but SPRTs try to reduce the average number of samples required to collect and achieves certain performance [30].

2. Parallel Based detector

In this detector the Secondary User is provided with multiple single band detectors. Each of single band detector senses a particular band one at a time. In this there are two types filter bank structure and frequency based parallel detector [23].

A. Filter bank detector

Graphical representation of filter bank structure is shown in Figure 16. Filter bank detector implementation is based on the prototype filter. The prototype filter is generally a low pass filter In principle of low pass filter any non-zero frequency point on filter response is used as reference point for the prototype filter. Low pass filter is used to find out zero^th band of filter bank structure. Other band can be detected by modulating the prototype filter.

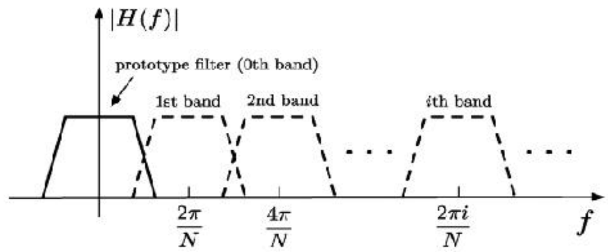

Figure 16:Graphical representation of filter bank structure [31]

Filter bank structure is shown in Figure 17(a). It consist of multiple band pass filter each carries with its own center frequency. This signal is the then passed through multiple single band detector parallely. The signal from the single band detector is then compared with the threshold λ_1 to λ_M parallely to decide the presence of primary user signal. The primary task of filter bank structure is to make easy multicarrier communication [31]. The figure below shows that filler bank structure consist of only one type of multiple single band detector so this structure can be extended by using (heterogeneous structure) multiple different single band detector [23].

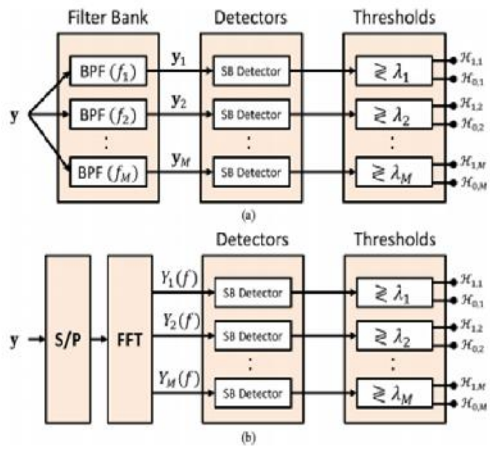

Figure:-17(a) Filter bank structure. (b) Frequency-based parallel detectors [23]

B. Frequency based parallel detector

The frequency based parallel detector is as shown in figure 17(b).Here the total wideband spectrum is divided into the frequency domain. This is done by using 1st block as serial to parallel convertor

followed by Fast Fourier Transform (FFT) before the signal is feeding to single band detector. Here the single band detector is considered as energy detector. Because in single band detector it is easy to compute energy in frequency domain by studying the power spectral density of the signal. The output of single band detector is then compared with threshold to detect the presence of primary signal [23]. This can be expressed as

$$T(x_m) = \sum_{n-1}^{N} |X_m(n)|^2 \qquad m = 1, 2.....,M \qquad (5)$$

Where $X_m(n)$ is the frequency domain of received signal x at the m[th] sub band. N here is the FFT size, each sub band has a own threshold in vector form as $\lambda = [\lambda_1, \lambda_2, \lambda_3, \lambda_4 ....\lambda_M]$[23].

C. Multiband Joint Detection Technique

Multiband Joint Detection (MJD) techniques jointly takes into account the detection of primary user signal over multiple frequency spectrum bands rather than considering over one band at a time. The basic method is to detect primary user signal jointly across a bunch of narrowband sub-bands rather than considering single band at a time [33].

Here to improve the aggregate opportunistic throughput of the Cognitive Radio Network, this technique jointly optimize the bunch of multiple narrowband sub-bands [32].

3. Wideband Based Detector

In wideband based detection spectrum sensing technique the multiband spectrum is used for detection of primary user. Here the primary communication is operating over wideband spectrum frequency bands which are divided into M non overlapping frequency band. By using the multiple techniques, they find out the some of the M sub channels might be vacant and not used by primary user in a particular geographic region with a particular time interval. This vacant sub channels are used by secondary users for the transmission of signal.The types including the wideband based detector as wavelet sensing (WS), Compressive sensing (CS), Angle Based sensing (ABS), and Blind Sensing (BS).

A. Wavelet Sensing

The assumption is that the secondary user knows the number of sub channels M and their corresponding location $F_1 ....F_M$ but practically this is not possible, to overcome this problem the wavelet based technique is developed . The wavelet based sensing method has the ability to determine and analysed singularities in wideband spectrum [23].

In wavelet based sensing method the detection and processing on singularities has been applied in many applications such as filtering, image processing, compression and in denoising. The wavelet approach wants to use the wideband spectrum hence it may require high sampling rate to identify the wideband spectrum bandwidth [34].

Author in [34] explains the new technique as Continuous Wavelet Transform (CWT) which is carried out in frequency domain to find out the singularities in wideband spectrum bandwidth. Here they detect the boundaries of sub channels without any prior knowledge of number of sub channels and their center frequencies. Once their edges are determined the power spectral density is calculated to determine the vacant sub channel for the usage of secondary user for transmission of signal.

The wavelet Based detector further classified into wavelet modulus maxima (WMM), wavelet multiscale product (WMP), wavelet multiscale sum (WMS). All these types have their own advantages and disadvantages [35].

B. Compressive sensing

Conventionally author in [36] said that according to shannons theorem to recreate the signal the sampling rate must be at least twice the maximum frequency in the signal this phenomenon is called as the nyquist rate. Suppose by considering an example if the wideband spectrum has the bandwidth 3GHz then the sampling rate must be 6GHz and this is very challenging design to implement and also there is difficulty in processing of signal. This problem is solved by using the compressive sampling. In compressive sampling the signal is sampled below the sampling rate which is also known as the compressive sensing [37].

Compressive sensing occupies the non adaptive linear projections which preserve the originality of the sampled signal which sample below the sampling rate and that signal will be reconstruct from these projection using optimization process algorithm [38].

C. Blind sensing

In blind sensing the structure of the received primary user signal in licensed spectrum is unknown at unlicensed user side [39]. Blind sensing detector acts like an energy detetctor in some extent where the prior knowledge of primary signal is not known [40]. In this both of below parameters are not known

- Primary user signal characteristics
- Noise background

Blind sensing can be achieved through information theoretic criteria(ITC) algorithms, Minimum description length (MDL) algorithm, Gerschgorin disc estimator(GDE)[40]. By using information theoretic criteria spectrum sensing for multi-primary user in frequency domain is performed. MDL is used to blindly detect the presence of primary user in frequency domain . MJD blindly detects the presence of primary user signal in multiband spectrum and aggregates the vacant band which are used by secondary user for transmission of signal for communication. For the wideband spectrum the MJD detection method is more suitable than any other methods [41].

IV. CONCLUSION

This paper presents the major spectrum sensing techniques in cognitive radio. This includes the single spectrum sensing technique and multiband spectrum sensing techniques. Multiband spectrum sensing techniques enhance the secondary users throughput which improves the quality of service. Hence Multiband spectrum sensing technique are popular than single band spectrum sensing techniques. Multiband spectrum sensing techniques has the advantage over the single spectrum sensing techniques. Here the analysis of the advancement in single band and multiband spectrum sensing techniques, their challenges and future enhancement is discussed.

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